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BIOLOGY IN SECONDARY SCHOOLS.

It is a significant and hopeful fact that thought was never more active than now in reference to all matters pertaining to education. It recognizes that old methods, suitable as they may have been to the times of their introduction, are not necessarily always applicable. We have learned that there is such a law as adaptation, and, that the spirit of to-day cannot find its full expression in the forms of yesterday. In church and state this law is at work, and the great problem before educators is to adapt their schemes to rapidly changing conditions. The power of prejudice, "the power of what has been over the frail form of what might be," is nowhere more prevalent than in existing schemes of education, and it is hard to banish all predisposition and face the problem with a judicial mind. One of the most vigorous attempts to get at the real issues in secondary education is to be found in the work of the nine conferences during holiday week, whose separate conclusions are yet to be brought together into a consistent whole. Whether the careful work of these conferences will have any immediate general effect upon secondary education is yet to be seen ; but it will at least prominently open a very fruitful subject for discussion. It is a subject also which vitally concerns colleges, as it involves discussion concerning their entrance requirements.

In responding to the request to discuss briefly the questions presented to the conference on Biology, I recognize at the outset that the human mind, like the human body, has great powers of endurance. Most of us daily violate one or more well-established hygienic laws, and yet the body seems to retain and develop sufficient vigor for its work. For generations developing minds have been subject to the most diverse theories of education, and yet each generation has had its share of mental power. However, laws for symmetrical and vigorous mental development must be formulated or no progress in education will be made.

A word should be said with reference to the subjects referred to the conference under the general head of "Natural History." This title should be entirely abandoned as synonymous with "Biology." The application of the latter term to the study of all living forms is too poorly understood in our schools to hazard

any further confusion. A worse evil in the use of terms is to group under "Natural History" or "Biology" the subjects "Botany, Zoology, and Physiology" as co-ordinates, as was done in the circular of instructions to the conference. Doubtless this was a concession to the terminology of the secondary schools, but I wish to protest against such a misapplication of the term "Physiology." That it should ever have been applied to the study of the anatomy and hygiene of the human body is strange enough, but that it should continue to be so applied is inexcusable. There is a physiology of plants and a physiology of animals, but these are departments of Botany and Zoology.

Taking the term "Physiology" as referring to the study of the human body, its place in any scheme of secondary education is so entirely different in purpose from that of Botany or Zoology that it cannot be considered in the same connection. It is chiefly used to give a certain amount of useful information rather than to study the human animal as a zoological subject. It thus becomes an informational study rather than a disciplinary one, and is not to be considered as a part of the subject of biology in secondary schools. For this reason I refer solely to Botany and Zoology in the following consideration of the questions submitted to the conference on Natural History.

1. *"In the school course of study extending approximately from the age of six years to eighteen years—a course including the periods of both elementary and secondary instruction—at what age should the study which is the subject of the conference be first introduced?"*

My unhesitating answer is that biological study should begin with the school course. One of the most natural powers of children is that of observation, and nothing is more interesting to them than the observation of living things. Far be it from me to say that the study of Botany or Zoology means the use of a book and the memorizing of technical terms; if so, they are not fit subjects for any stage of advancement. The pupils should be made to know that Botany is not a book, but is the world of plant life all about them, and it will lose all of its terrors. The most common failure of our elementary and secondary schools is that they cause to become blunted this keen instinct for the observation of natural objects which is a notable endowment of children. "Study" and "books" become synonymous terms

with them, and their conception of knowledge is that of something to be obtained at "second hand." The study of plants and animals is one of the most effective methods of counteracting this tendency, but the effectiveness will depend upon the method of teaching. If the attempt is made to give a consecutive and complete view of the plant or animal kingdom to young children, it will be disagreeable and sterile work. If a haphazard selection of material is made, observation may be somewhat encouraged, but a grievous wrong is done in presenting facts that hold no relation to each other. Such work needs both knowledge of children and knowledge of Biology. I have been surprised to hear it urged as an objection to this early introduction of biological study that it requires more knowledge of the subject than our teachers possess. If there is a strong demand for such teaching, will not the teachers be forthcoming? Should we only teach those things that teachers "happen" to be able to teach? Demand the teaching and the teachers will prepare, and never was biological instruction easier to obtain. In some schools these elementary "nature studies" are most effectively combined with other work, such as drawing, language, etc. To observe, to sketch, to express, are all worth cultivating.

As a botanist I would like to say that next to the injustice of compelling children to regard Botany as a book, is that of leading them to think that it is a study of flowers, and that its sole purpose is to teach them how to "analyze" flowering plants. A zoologist would likely complain if his noble science were presented as the study of legs, useful and ornamental as these organs may be, or were restricted to the naming of a few birds or mammals. How many who teach Botany are laboring under the impression that Botany can be taught only while flowers are blooming? Plants are always with us, and are always fit subjects for study; and is not a moss, or a toadstool, or a seaweed as truly a plant as a buttercup? The only difference is that a buttercup is far more difficult to understand than the others, and is not so fit a subject for elementary study. It is ignorance that makes the toadstool seem difficult and the buttercup easy. Are the starfish, the seurchin, the worm, the clam, the crayfish, the host of insects, all to be mentioned, and "invertebrate plants" ignored? From my own personal experience, and from the testimony of others, I know that children make no such distinctions and find no such difficulties, and in this they follow nature.

2. *After it is introduced, how many hours a week for how many years should be devoted to it?*

The purpose of the work furnishes the answer to the question. If it is to prevent the atrophy of the observing powers, and at least to keep them functional, the work should be reasonably continuous. In primary and grammar grades one or two exercises each week through all the years would serve to keep the eyes open. When properly conducted these exercises are as eagerly looked forward to as the recreation periods, and I have in mind certain "country schools" which have become veritable museums in their display of plants and animals, where the weekly excursion touches the very heart of Nature, and the hour of "Nature study" brings closed books and eager faces. In visiting such a school one needs not to be told that not only are the eyes kept open but fresh vigor is obtained for other work.

A word might be said as to the manner of conducting such work. In the case of small animals, such as starfish, crayfish, etc., interest is aroused by having the pupils first study them alive, watching their motions, observing all external features, etc. In the case of plants, while different forms are in cultivation and their growth watched, specimens are placed before the pupil for more careful study, such as a leaf, a toadstool, a fern, a seed, a twig, a lichen, a rockweed, etc., etc. Then they are told to sketch it, and this secures close observation, until the external appearance has fully impressed itself upon them. When more advanced, in addition to external observation, the pupil is directed to section the specimen in various ways, and discover whatever of internal structure he can. Then there is a time for reporting observations and a general comparison of results, which stimulates more searching examination and gives an opportunity to cultivate the art of expression, which must be accurate both in form and fact. These suggestions are of the most general kind, but from them the apt teacher can catch the spirit of such work.

3. *How many hours a week for how many years should be devoted to it during the last four years of the complete course; that is, during the ordinary high school period?*

I recognize the fact that the high school period is very much crowded, and that other than the biological sciences demand recognition. However, that some time should be devoted to the

study of life-forms hardly needs any argument. If this be conceded, the minimum amount of time can be easily stated as one year of daily exercises. Nothing short of this counts for much in any science, and this minimum amount of time should not be divided between the two biological sciences, but should be given entirely to one or the other. The methods and principles of the two are so nearly identical that to do both is duplicating work to a certain extent. I am taking for granted that the chief purpose of both these subjects in secondary schools is to develop power, and to come in contact with the problems of life, and not to give information about plants and animals. Anything less than a year in either subject is to be avoided since the best result, the development, comes after the alphabet and preliminary definitions are passed. It is the great fault of our secondary education, and of much college education, that subjects are dropped just when they might begin to be made effective. The choice between Botany and Zoology should be left to the training of the teacher, who in every case should be expected to do what he can best do. In case the secondary school is fortunate enough to secure the services of a teacher in each of these subjects, the choice could well be left to the pupil. It must be clearly understood that a minimum amount of time is not necessarily the optimum amount, and it would be well for any secondary school to offer the opportunity of more than one year in both Botany and Zoology. Too much emphasis cannot be placed upon the statement that the work should be conducted entirely by the laboratory method. I know that this statement is becoming a very trite one, and that as the science-teaching of the secondary schools is inevitably getting more and more into the hands of our university graduates the methods are being vastly improved, but my intimate acquaintance with the schools assures me that there is yet much to be desired, and that the same amount of energy more wisely directed could be made far more effective. I am still being repeatedly shocked at the current conception of Botany. Blank-books for "analysis" are multiplying, and demands are still being made upon the innocent pupil to prepare an herbarium, and these demands are emphasized in certain quarters in college entrance requirements. All these things are pleasant enough, and in a certain sense instructive, but they should not stand for Botany, or be considered as giving any adequate impression of the plant kingdom. Such

work is merely incidental in the science of Botany, and can only be made critical and effective among advanced students. As one who has given much of his time in the preparation of "manuals," I cannot be considered as prejudiced in speaking of the injurious effect of their exclusive use in elementary instruction.

In any effective work in Botany in the high school no books should be put into the hands of the pupil except laboratory guides or books of reference. Each place at the laboratory tables should be furnished with a compound microscope and a few ordinary reagents. A careful study of typical plants should be made, plants not selected at random, but to represent prominent groups and phases of development. The danger in such a method is that this study of types too often becomes a study of isolated and hence barren facts. The relation of any observed fact to the rest of the world must always be kept in mind, and the pupil urged to draw tentative conclusions. I have seen most excellently equipped teachers who only succeed in drenching pupils with facts, which apparently no more fit into each other than do the words of an alphabetically arranged dictionary. This evil becomes greater when the teacher who is a master of delicate manipulation leads his pupils astray into the mysteries of sectioning and stains, and teaches only the machinery of the science. But if the pupil is to get from Biology a type of training that no other study can give, he must be made to work with the subject-matter itself, and make investigations which are original from his point of view. To weave these observed facts together so as to form some sort of fabric with a pattern is the test of the real teacher, and for this reason frequent questioning and frequent lectures are very essential in all such elementary work. A common and good division of the five weekly periods is to give three of them to laboratory work, one to quizzing, and one to informal lecturing. Some laboratory teachers make the serious mistake of leaving young students too much to themselves. These students must learn to work independently, but they must learn to work effectively, and that too without wasting too much time in committing useful blunders.

4. *What topics, or parts, of the subject may reasonably be covered during the whole course?*

5. *What topics, or parts, of the subject may best be reserved for the last four years?*

These questions can better be answered together. The field of Zoology or of Botany is so enormous that one may well pause to raise the question as to what vistas of it may be most profitably revealed. To present either subject in all its departments is simply out of the question, but there seems to be a natural introduction to both. To get some general conception of the subject-matter is the first step, and the only one that the pupil of secondary schools can take. He must first take a general survey of the plant kingdom, or of the animal kingdom; not by having either pass before his eyes like a panorama, but by making the personal acquaintance of a few typical forms. To read descriptions or even to look at pictures will not make a traveler, for the subtle influence of personal experience cannot be put into description. To put it technically, this proper introductory view is to be obtained by a study of the general comparative morphology of plants or animals. In the grades below the high school this must be confined to such facts as can be obtained by keen eyes, aided it may be by the occasional use of the simplest lenses; in short, such facts as may be included under the head of gross anatomy. Nearly all of the great groups of plants and animals can be so studied. The suggestive forms to select I shall speak of presently, when more definitely describing the work that can be done in the high school; the only difference being that in the work of the latter a deeper insight is to be obtained by the use of compound microscopes.

In the solid year of high school work that view of comparative morphology is to be obtained whose facts can be included under the head of minute anatomy. Lest I should be misunderstood at this point by botanists and zoologists I am compelled to explain that function should never be separated from structure, and that, of course, any study of the structure of an organ is simply preliminary to raising the question as to its function. From my point of view, therefore, any study of comparative morphology is not only bound up with general physiology, but loses its whole point when this is lost sight of. Not all questions as to function can be answered, for Physiology is yet in its infancy, but it is none the less important that such questions be continually raised. In order to be definite, I desire to submit a suggestive course of study for such a year of work in Botany, and the principles involved can easily be applied to Zoology.

The study of a plant consists of the examination of all its es-

sential features, such as cell-structure, its mode of development, its reproduction, in short, as much of its life-history as possible. Careful examination must always be secured by careful sketching, and upon this too much stress cannot be laid. It is much more satisfactory and scientific to begin with the study of the simplest forms, not merely because they are far easier to understand, but also because this order of study will give some notion of the evolution of the plant kingdom. The many advantages of this order of study, advantages which have been seen in much experience, should outweigh any supposed advantage in beginning with the study of the most complex plants. In my own experience both methods have been tried, and in beginning with flowering plants and then afterward approaching them from the lower forms, I have invariably found that previous wrong conceptions of the higher forms had to be corrected. I thoroughly believe that no proper notion of higher groups can be obtained without previous study of the lower ones. A suggestive working list of plants is as follows, although others will do just as well, and the convenience of material must determine the selection :

1. *The simplest forms* can be represented by the green slimes, such as species of *Chroococcus* and *Oscillaria*, both to be found everywhere. These forms could be supplemented by others, such as *Nostoc*. It would not be advisable to attempt any study of *Bacteria*, but they should be demonstrated and their great importance indicated.

2. *The green algæ* should be studied by means of such forms as *Protococcus*, *Cladophora*, *Ædogonium*, *Spirogyra*, *Vaucheria*, etc. It would be a very remarkable region in which all of these forms could not be found abundantly.

3. *The brown algæ* are well represented by the common *Fucus* or "rockweed" and *Laminaria* or "kelp," which can be obtained in abundance from the seashore.

4. *The red algæ*, also to be obtained from the seashore, can be studied with such common forms as *Callithamnion*, *Polysiphonia*, *Chondrus*, *Corallina* or *Grinnellia*, etc. It may be objected at this point that the brown and red seaweed are not within the reach of inland schools, but the very slight trouble of providing them is hardly worth considering. They can be dried, kept indefinitely, and soaked when desired for use ; or they may be preserved in jars of weak alcohol.

5. *The fungi* should be represented by such plants as *Mucor*, *Cystopus*, some common powdery mildew (such as that formed on lilac leaves), a cup fungus, a lichen, some rust (such as wheat-rust), a puff-ball, and a toadstool.

6. *The stoneworts* (*Chara* or *Nitella*) should be studied if material is convenient.

7. *The Bryophytes* would be fairly represented by the study of a single liverwort and moss.

8. *The Pteridophytes* could be studied in some ordinary fern, and any greenhouse will furnish a supply of fern prothallia. If possible, the view of the group should be enlarged by the examination of an *Equisetum* and Club Moss.

9. *The Gymnosperms* are well represented by the common *Pinus sylvestris*.

10. *The Phanerogams* should be represented by a monocotyledon (such as *Trillium* or *Erythronium*), and a dicotyledon (such as *Capsella*).

Such a list of forms would give the student a very intelligent notion of the plant kingdom. Of course, it would not be at all advisable to attempt the study of as many plants as have been mentioned, for thorough work must never be sacrificed to numbers; but selections of material should be made from each of the nine or ten groups given, and even a single example under each would be far more valuable than entire neglect. If it is claimed that many of these forms are entirely unfamiliar to teachers, it can only be said that under such circumstances the study of any forms could hardly be profitable.

It is very desirable, moreover, that this year of work be continuous, beginning with the fall and continuing uninterruptedly to the summer vacation. A little foresight will enable the teacher to provide all the necessary material for work during the winter.

6. *In what form and to what extent should the subject enter into college requirements for admission?*

If a year of this work is held to be a minimum requirement for secondary schools, this same amount should be included in the admission requirements for college. I am coming more and more to regard our venerated entrance requirements as demanding a "lop-sided" development, and I am compelled to say that this demand for one-sided students is greater in the East than in the West, possibly on account of the greater conservatism of the

former. I must confess that along with my great love for the classics there will intrude the conviction that a little less language and a little more laboratory science in college entrance requirements would better prepare a student for the varied activities of college work. It may be said that tremendous doses of language should be taken when memory is the dominant mental power, but I am only suggesting that the dose might be slightly reduced so as to give place to a little of other treatment. The fact of the matter is that the average student who has come to the age for entering college without any laboratory training comes with encrusted eyes. So long has he been denied the privilege of seeing for himself that he cannot see at all, and entrance into the college laboratories means a long preliminary surgical operation before he can begin to work. My only plea is that enough laboratory work be included in the admission requirements to insure that the applicant has had his eyes kept open. As to the "form" of examination I would say at once that it should not be "a written examination on a text-book." This insisting that any great subject is a book is so far from my notions of education that I cannot appreciate the necessity of the question. Examinations, as I understand them, are not to test the capacity of a man's mental stomach, but to discover the amount of permanent tissue he possesses. We seek then to discover not his memory of a book, but his working power. With this in view any entrance examination in Biology should be three-fold: (1) The submitting of laboratory note-books, to show the scope and character of the previous work; (2) a written examination on the elementary principles of the subject (not "on a text-book"); and (3) a laboratory test, to show what the applicant can do.

7. Should the subject be treated differently for pupils who are going to college, for those who are going to a scientific school, and for those who, presumably, are going to neither?

8. At what stage should this differentiation begin, if any be recommended?

The work already suggested is thought to be the proper general introduction to the study of either Botany or Zoology. It is little more than the alphabet of the subject, and is the natural beginning, whatever may be the future purpose of the student. It can be considered as merely introductory, or as complete in itself; it is certainly not only the best preliminary course but also the best

short course. It must be understood that any course in science in the secondary schools becomes a good preliminary course only when it involves laboratory training and a proper conception of the subject. If it is text-book work or laboratory work in a very restricted field, leading to an entire lack of appreciation of the spirit and range of the subject, such preparation is positively injurious. This latter kind is so very common that college instructors in science are apt to confess frankly that they would much prefer no science in the preparatory schools. Such a statement, however, is not a reflection on the subject and a confession of its unfitness for college preparation, but a reflection upon the teaching.

9. *Can any description be given of the best method of teaching this subject throughout the school course?*

10. *Can any description be given of the best mode of testing attainments in this subject at college admission examinations?*

Both of these questions have been answered in the course of the preceding discussion.

11. *For those cases in which colleges and universities permit a division of the admission examination into a preliminary and a final examination, separated by at least a year, can the best limit between the preliminary and the final examinations be approximately defined?*

If a single year of biological work is required for admission, any such division of the examination is certainly unnecessary and unwise. If, however, two years of such work are required, the examination might be divided, but with no more than one year between preliminary and final examinations. In such a case the preliminary should cover a general survey of the plant or animal kingdom, as has been outlined above, with suitable laboratory tests; and the final could well demand more special and critical work in some definite region of the subject.

It is very probable that other questions will arise as this general subject becomes more and more widely discussed, and the views of college men and school men may be expected to differ in many particulars in reference to secondary schools, one claiming superior knowledge of the subjects taught, and the other, superior knowledge of the situation. It is just these two points of view that must not longer be kept separate, and the best interests of secondary education will be conserved when they are made to harmonize.

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